

C6
81. (Amended) The carbon foam of claim 80 characterized by an X-ray diffraction pattern exhibiting relatively sharp doublet peaks at 2θ angles between 40 and 50 degrees and an average d002 spacing of about 0.336.

C10
128. (Amended) The carbon foam of claim 56 wherein the carbon foam is a non-oxidatively stabilized foam derived from a mesophase pitch, the carbon foam having an open cell structure and a specific thermal conductivity greater than copper.

C11
131. (Amended) The carbon foam of claim 56 wherein the carbon foam is a non-oxidatively stabilized foam derived from a mesophase pitch, the carbon foam having an open cell structure and a bulk thermal conductivity from about 58 W/m·K to about 106 W/m·K.

REMARKS

This Reply is in response to the Office Action dated November 14, 2002. This Reply is filed within the three-month shortened statutory period, and is thus timely filed.

Claims 56-84 and 128-131 were pending at the time of the Office Action. In the Office Action, claims 56-74, 76-78, 80-82 were rejected. Claims 75, 79, 83, 84, 128-131 were objected to as being dependent on a rejected base claims, but were determined to be allowable if written in independent form incorporating all limitations of their respective base claims and any intervening dependent claims. In this Reply, claims 56, 58, 60, 65, 66, 69, 71, 72, 76, 78, 80, 81, 128 and 131 have been amended. No new matter has been added. The amended claims are shown in a section entitled Marked-Up Version

To Show Changes using standard underlining and bracketing format to highlight the changes made.

Claim 58 was rejected under 35 U.S.C. §112, second paragraph, as being indefinite for failing to particularly point out and distinctly claim the subject matter which Applicants regard as the Invention. In response, Applicants have replaced the phrase "non-solid state" with the phrase "a liquid or a gaseous state". Accordingly, the 35 U.S.C. §112, second paragraph rejections is overcome.

Claims 56-74, 76-78 and 80-82 were rejected under 35 U.S.C. §102(b) as anticipated by or, in the alternative, under 35 U.S.C. §103(a) as obvious over U.S. Patent No. 4,806,290 to Hopper et al. ("Hopper"). Claims 56-59 were rejected under 35 U.S.C. §102(b) as anticipated by or, in the alternative, under 35 U.S.C. §103(a) as obvious over U.S. Patent No. 3,979,196 to Frank et al ("Frank").

According to the Examiner:

Hopper teaches in column 6 graphite foam with water. It appears that the water impregnates the graphite; no differences are seen. The properties not disclosed are deemed met since it is a high porosity graphitic material.

Applicants respectfully traverse the above claim rejections based on the above reasoning which asserts that the foam disclosed by Hopper is a "high porosity graphitic material" and as a result meets Applicants' claimed limitations.

Hopper discloses machinable and structurally stable, low density microcellular carbon, and catalytically impregnated carbon, foams, and process for their preparation. Pulverized sodium chloride is classified to improve particle size uniformity, and the classified particles may be further mixed with a catalyst material. The particles are cold pressed into a compact having internal pores, and then sintered. The sintered compact

is immersed and then submerged in a phenolic polymer solution to uniformly fill the pores of the compact with phenolic polymer. The compact is then heated to pyrolyze the phenolic polymer into carbon in the form of a foam. Then the sodium chloride of the compact is leached away with water, and the remaining product is freeze dried to provide the carbon, or catalytically impregnated carbon, foam. Hopper does not provide any thermal conductivity values.

Column 6, lines 13-28 (copied below) of Hopper teach the use of heat treatment of no more than 725 °C:

The phenolic polymer generally leaves behind about half of its original mass as carbon when slowly pyrolyzed to approximately 600 to 700 degrees centigrade in this operation. The pyrolysis of phenolics has been widely studied and is described in publications such as "Polymeric Carbons-Carbon Fibre, Glass and Char", by Jenkins et al, Cambridge University Press (1976), and "Heat-Resistant Polymers", by Critchley et al, Plenum Press (1983), both of which are incorporated by reference herein. Thermal expansion mismatches, the 825 degree centigrade melting point of sodium chloride, and the rapid densification of sodium chloride by sintering above about 750 degrees centigrade, all combine to *prohibit this pyrolyzing step from being performed at any temperature above about 725 degrees centigrade.* (italics for emphasis only).

Applicants note that those having ordinary skill in carbon science recognize that a high temperature heating step (e.g. at least 2500 K) is required, but may not be sufficient, to convert carbon foam to graphitic foam. Hopper does not mention "graphitization" or "graphitisation" which are terms which have generally been used by ordinary artisans in the field of carbon foams to indicate only that a high temperature heat treatment (e.g. at least 2500 K) has been applied to a carbon foam material. Indeed, a "graphitization" step does not even necessarily produce graphite. Moreover, even if a graphitization step produces graphite, and even if a highly aligned graphitic structure results, the resulting foam may still be thermally insulating.

High thermal conductivity carbon foams are evidenced by long range crystallographic order and high fraction of perfect graphene layers which are required to produce high thermal conductivity. In fact, the term "graphitization" has been so frequently misapplied that American Society of Testing and Materials (ASTM) recently adopted a more objective definition of "graphitization." This ASTM definition, which is consonant with the IUPAC definition of graphitization for about the last 10 years, reads as follows:

- **Graphitization** – *in carbon and graphite technology*, a solid state transformation of thermodynamically unstable non-graphitic carbon into graphite by thermal activation.
 - Discussion: The degree of graphitization is a measure of the extent of long-range crystallographic order and is related to the fraction of perfect graphene layers in the structure and determined by diffraction studies only. The degree of graphitization affects many properties significantly, such as thermal conductivity, electrical conductivity, strength, and stiffness.
 - Discussion: A common, but incorrect, use of the term graphitization is to indicate a process of thermal treatment of carbon materials at $T > 2500\text{K}$ regardless of any resultant crystallinity. The use of the term graphitization without reporting confirmation of long range crystallographic order determined by diffraction studies should be avoided as it can be misleading.

Thus, as discussed above, Hopper does not even include a "graphitization" step as the highest disclosed processing temperature is 725 °C. Without a graphitization step Applicants' claimed essentially graphitic foam cannot be provided. Thus, amended claim 56 and all claims dependent thereon are patentable over Hopper since Hopper teaches away from Applicants' claimed invention.

Even references other than Hopper which may disclose a "graphitization step" do not generally produce a graphitic foam because the term "graphitization" can be misleading as it has been commonly used regardless of any resulting crystallinity. The

application for the present invention and other Oak Ridge National Laboratory (ORNL) foam applications, including applications in which the present invention claims priority, report and claim X-ray diffraction derived crystalline parameters which represent independently patentable subject matter. For example, the present application claims 20 values of between 40 and 50 degrees (claim 66) and interlayer spacing d_{002} (claim 64) which both confirm the presence of long range crystallographic order and a high fraction of perfect graphene layers. In addition, several claims recite high thermal conductivity related values, such as claims 60, 65, 69, 80 and 129.

Claims 56-59 were rejected as being anticipated, or in the alternative, as being obvious over Frank. According to the Examiner "Frank teaches glassy carbon with water in the pores in column 3. Applicants agree with the Examiner's characterization of Frank as being glassy carbon with water in the pores but respectfully disagrees with the Examiner's conclusion that Frank's glassy carbon with water in the pores can anticipate or make obvious Applicants' claimed invention which recites an essentially graphitic carbon foam as explained below.

Frank discloses the undulation of hot-moulded glass is avoided when the cooling of the glass edge layers in the first phase of the moulding operation is delayed and is accelerated after completed moulding. This is achieved by using a mould of a glassy carbon having a porous structure. Prior to the moulding, the pores are filled with a gas-forming liquid or a gas. The resulting gas film between the glass and the surface of the mould is removed after completed moulding. The pores may subsequently be filled with a cooling agent.

Frank discloses (col. 2, lines 33-39) the "adaptability of the foamed material of glassy carbon to the requirements of the glass working methods" including the pore characteristic, the density, as well as the shape and homogeneity which can be varied considerably to adjust the thermal conductivity of the glassy carbon "within certain limits". However, the disclosed thermal conductivity range is clearly always insulating (between 0.042 and 0.42 W/m·K) as disclosed in col. 2, lines 57-64:

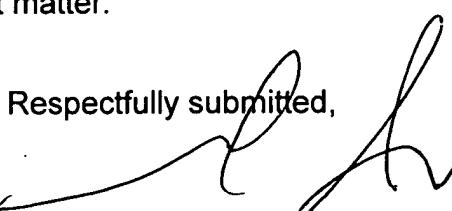
These wishes are met by the material used in the method according to the invention since it has a comparatively poor thermal conductivity. Said thermal conductivity is between 10^{-4} and 10^{-3} cal. $^{\circ}\text{C}^{-1}.\text{cm}^{-1}.\text{s}^{-1}$ (between 0.042 and 0.42 W/m·K) in accordance with the density. Due to the comparatively poor thermal conductivity too rapid a cooling of the glass edge layers in the first phase of the moulding operation is avoided.

Significantly, glasses are defined as any of a large class of materials with highly variable mechanical and optical properties that solidify from the molten state without crystallization. Thus, Frank's glassy carbon is clearly amorphous, amorphous glass being the antithesis of Applicants' claimed essentially graphitic carbon foam which is crystalline. Accordingly, Applicants submit that amended claim 56 and claims dependent thereon are patentable over Frank. Claims which disclose thermal conductivity values or X-ray diffraction derived crystalline parameters as noted relative to Hopper add further patentable subject matter.

Date: 2/10/23

Docket No. 6321-157

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Marked-Up Version To Show Changes

IN THE CLAIMS:

56. (Amended) A carbon foam containing a phase change material in at least some of its pores, wherein the foam is an essentially graphitic carbon foam.

58. (Amended) The carbon foam of claim 56 encased to prevent loss of the phase change material when [in a non-solid state] said phase change material is in a liquid or gaseous state.

60. (Amended) The carbon foam of claim 56 wherein the foam [is an essentially graphitic carbon foam having] provides a bulk thermal conductivity greater than about 58 W/m·[°]K.

65. (Amended) The carbon foam of claim 58 wherein the foam [is an essentially graphitic carbon foam having] provides a bulk thermal conductivity from about 58 W/m·[°]K to about 106 W/m·[°]K.

66. (Amended) The carbon foam of claim 65 characterized by an X-ray diffraction pattern exhibiting relatively sharp doublet peaks at $2[q]$ θ angles between 40 and 50 degrees.

69. (Amended) The carbon foam of claim 56 wherein the foam [is an essentially graphitic carbon foam having] provides a specific thermal conductivity greater than about 109 W·cm³/m·[°]K·g.

71. (Amended) The carbon foam of claim 69 characterized by an X-ray diffraction pattern having an average d002 spacing of about 0.336 and exhibiting relatively sharp doublet peaks at $2[q] \theta$ angles between 40 and 50 degrees.

72. (Amended) The carbon foam of claim 56 wherein the foam [is an essentially graphitic carbon foam having] provides a specific thermal conductivity from about $109 \text{ W} \cdot \text{cm}^3/\text{m} \cdot [{}^\circ]\text{K} \cdot \text{g}$ to about $200 \text{ W} \cdot \text{cm}^3/\text{m} \cdot [{}^\circ]\text{K} \cdot \text{g}$.

76. (Amended) The carbon foam of claim 56 wherein the foam [is an essentially graphitic carbon foam having] provides a specific thermal conductivity greater than copper.

78. (Amended) The carbon foam of claim 77 characterized by an X-ray diffraction pattern exhibiting relatively sharp doublet peaks at $2[q] \theta$ angles between 40 and 50 degrees.

80. (Amended) The carbon foam of claim 56 wherein the foam [is an essentially graphitic carbon foam having] provides a specific thermal conductivity greater than four times that of copper.

81. (Amended) The carbon foam of claim 80 characterized by an X-ray diffraction pattern exhibiting relatively sharp doublet peaks at $2[q] \theta$ angles between 40 and 50 degrees and an average d002 spacing of about 0.336.

128. (Amended) The carbon foam of claim 56 wherein the carbon foam is a non-oxidatively stabilized[, essentially graphitic carbon] foam derived from a mesophase

pitch, the carbon foam having an open-cell structure and a specific thermal conductivity greater than copper.

131. (Amended) The carbon foam of claim 56 wherein the carbon foam is a non-oxidatively stabilized[, essentially graphitic carbon] foam derived from a mesophase pitch, the carbon foam having an open cell structure and a bulk thermal conductivity from about 58 W/m·K to about 106 W/m·[°]K.